The Role of Fluid Mud in Sediment Transport Processes Along a Muddy Coast

Gail C. Kineke
Dept of Geology and Geophysics
Boston College
Chestnut Hill, MA 02467
phone: 617-552-3655 fax: 617-552-2462 email: kinekeg@bc.edu

Award # N00014-98-1-0083

LONG-TERM GOALS

The long-term goals of this study are to evaluate the role of high-concentration sediment suspensions (fluid mud) in sediment transport processes along muddy coastlines. This requires an understanding of the formation and dynamic behavior of fluid muds, as well as the effects on attenuation of surface waves as they approach the shoreline.

OBJECTIVES

The motivation for this study comes from the recognition that work done on sandy beaches is not directly transferable to muddy coasts, and that the role of fluid mud is critical to large-scale beach changes on muddy coasts. This study addresses the following objectives:

1. to examine the formation of fluid mud on the inner shelf as the result of a) trapping due to convergence of bottom flows and enhanced settling at a salinity front, or b) a resuspension process due to surface wave activity;

2. to test the concept of a critical bearing capacity for a flow, based on results of Trowbridge and Kineke (1994); and

3. to document the attenuation of wave energy over an inner shelf with fluid muds and relate that to areas of shoreline accretion and erosion.

APPROACH

The study area is the shallow shelf (< 20 m water depth) from Atchafalaya Bay to ~ 100 km west along the western Louisiana coast. Spatial surveys consisting of a series of shore-normal transects have been repeated during different river discharge conditions to define the thickness and extent of fluid muds in relation to water properties (extent of freshwater plume and nearshore mudstream). An instrumented profiling tripod capable of measuring flow and fluid characteristics (Sternberg, et al., 1991) and a second, hand-deployable profiler (CTD plus optical backscatterance sensor) for shallow water work have been used. The profiling tripod has been used for spatial surveys (shore normal transects throughout the study area), as well as for longer time series while the ship is at anchor. The hand-deployable profiler is used off a small boat in water shallower than approximately 5 m. In addition, the small boat is equipped with a dual high frequency echo sounder and differential GPS for mapping

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **The Role of Fluid Mud in Sediment Transport Processes Along a Muddy Coast**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Dept of Geology and Geophysics,,Boston College,,Chestnut Hill,,MA, 02467**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The long-term goals of this study are to evaluate the role of high-concentration sediment suspensions (fluid mud) in sediment transport processes along muddy coastlines. This requires an understanding of the formation and dynamic behavior of fluid muds, as well as the effects on attenuation of surface waves as they approach the shoreline.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

thickness and extent of nearshore fluid muds and unconsolidated bottom sediments. Analysis of short-lived radioisotopes from shallow water cores is combined with a detailed description of the coast to characterize areas of accretion and erosion in order to link resuspension and transport events with recent evolution of the coastline. An array of three pressure sensors were deployed at depths of 16, 11, and 2 m, to obtain time series of wave characteristics through events of cold front passages, and to evaluate attenuation of wave energy across the shallow shelf. Continuous measurements have also been made using a bottom tripod with an ADCP and continuous recording OBS. A prototype instrument to document vertical changes in differential pressure, and thus changes in fluid density, from within the mud bed to ~1.5 m above the bed continues to be modified and tested.

WORK COMPLETED

Five cruises have been completed aboard the R/V Pelican: October 1997-low river discharge, March 1998, 1999, 2001 -rising river discharge, high energy (wind and wave), and April 1998-high river discharge, diminishing energy. Data collected on these cruises include hydrographic/suspended sediment surveys of 45 stations along seven shore-normal transects, time series measurements of 12-55 hours at several locations, shallow water surveys with the echosounder and CTD profiler, and coastal characterization. Wave sensors have been deployed in a cross-shelf array in 1999 and 2001 for three and six week time series, respectively. The prototype differential pressure sensor was field tested in 2001 and is currently being modified.

RESULTS

It is apparent that high-concentration sediment suspensions are ephemeral on this shallow shelf, dominated by rapid clearing of the water column after a resuspension event, typically associated with cold front passage. The role of trapping of sediments in areas of enhanced stratification and convergence at fronts appears to be most significant in the dredged Atchafalaya River channel, and is less important on the shallow shelf. The presence of high concentration sediment suspensions is only indirectly related to river discharge, i.e. a supply of recently delivered sediment is necessary for resuspension, but fluid muds are not persistent at fronts on the shelf that may result from a discharge event. Resuspension due to waves appears to be critical to seed the water column with sediment, but the high concentration suspensions form as the result of rapid settling rather than through fluidization of the seabed. These high concentration suspensions are on the order of a few g/l concentration, thus are somewhat borderline for classifying them as fluid muds, which typically have concentrations > 10 g/l. Conditions have not been adequate to test Objective #2.

Results now focus on four general areas: 1) large scale distribution of the freshwater and sediment plumes; 2) cross-shelf attenuation of wave energy; 3) water column and suspended sediment response to the passage of cold fronts; and 4) coastal characterization.

1) The large-scale surveys show little relation between the freshwater plume and the sea surface sediment concentrations. Sediments are deposited close to shore during high river discharge, likely in a seasonal deposit, and are then reworked throughout the year with most transport onshore and to the west, mostly during December through April (Allison et al., 2001). The surface sediment plume is more related to wind speed and direction than river discharge.

2) Time-series measurements of wave characteristics at three cross-shelf locations show significant reduction in wave energy as the waves approach the shore, as much as 60-90 % over a distance of 24 - 34 km, with water depths varying from 16 m to 2 m. A friction factor two-orders-of-magnitude greater than that suggested for a smooth bed (Dean and Dalrymple, 1981) is necessary to accomplish the observed reduction in wave amplitude from offshore deepwater measurements to our observations in intermediate and shallow water. This could be indicative of the influence of fluid mud or an unconsolidated seabed.

3) Our most recent cruise, March 2001, yielded the most comprehensive data set documenting the response of the water column and subsequent sediment transport to the passage of cold fronts. Figure 1 shows one such event through a 55-hr time series of water column suspended-sediment concentration, salinity, and temperature (Fig. 1 A,B,C); wind direction and speed (Fig. 1D,E); continuous nearbottom (z=20cm) suspended-sediment concentration, shear velocity (current only), and significant wave height (Fig. 1F,G,H); and across- and along-shore depth-averaged currents and sediment fluxes (Fig. 1I,J). These data are the combination of hourly water column profiling in 5 m water depth, continuous bottom mounted ADCP and OBS3a measurements at the same site, and continuous pressure sensor measurements somewhat offshore at a water depth of 12m.

The cold front passage is characterized by the evolution of wind direction and speed (Fig. 1D,E). Pre-front (JD66.5 – 67.25) conditions are increasing winds from the southeast. Winds reach a maximum as they quickly change to a westerly and then northerly direction with the passage of the front (JD67.25-67.7), and then rapidly diminishing winds from the north to easterly direction during post-front conditions (JD67.7- 68.7). The water column responds rapidly to the changing winds with the breakdown in stratification in terms of salinity and temperature, and mixing of sediments throughout the water column during pre-front conditions, as well as the re-establishment of stratification during post-front conditions (Fig. 1A,B,C). Nearbed sediment response (Fig. 1F) demonstrates the importance of the combined influence of waves and currents. Shear velocity (Fig. 1G) was calculated for current only, the dashed red line indicates a typical resuspension threshold, and nearbed sediment concentrations do not show significant increases until the significant wave heights increase, after JD67 (Fig. 1H). The mean currents respond to wind speed and direction and the resulting sediment fluxes are linked to the timing of sediment resuspension (Fig. 1I,J).

Waves combined with currents cause the greatest resuspension and mixing throughout the water column during onshore winds. Once the winds change to the northerly direction, waves decrease and stratification becomes re-established. Thus the net transport for these events will typically be onshore and to the west. While waves enhancing resuspension has long been recognized, there is an additional influence of the waves through attenuation as the waves cross the shallow shelf, after sediments have settled to form nearbed high concentration suspensions. This may produce a positive feedback, preventing wave energy from reaching the coast and increasing the likelihood of coastal accretion and accumulation on the shallow shelf.

4)The results of the coastal characterization study has revealed spatially variable trends in erosion and accretion. In general, accretion is occurring along the chenier coast west of Freshwater Bayou, with a mud wedge, apparent in echo sounder surveys, that thins to the west. Short-lived radioisotope analyses also show a surficial layer close to shore that thins to the west. While budgets have not been calculated, it is clear that a significant portion of sediment from the Atchafalaya is being transported on shore and accumulating in the nearshore/coastal region.

IMPACT/APPLICATIONS

A tremendous amount of research on coastal processes and sediment transport has occurred on sandy beaches; however, muddy coasts are quite common worldwide, especially close to large rivers, and have received relatively little attention by comparison. Wave attenuation is of primary significance for mitigation of shoreline erosion and coastal flooding, and wave attenuation on a muddy coast is directly linked to the characteristics and consolidation state of the muddy substrate, unlike sandy shorelines. The most recent observations from this study lead to some intriguing implications. The cycle of cold front passages, combined with wave attenuation, yields accumulation of muds on the shallow shelf and coast. Perhaps an unusually energetic winter with numerous cold front cycles leads to greater accretion. This would be in stark contrast to the NE coast of the US, where repeated winter storms lead to extensive erosion. The nearshore mud wedge is also an interesting contrast to shelves like the Eel, which is characterized by a mid-shelf mud deposit.

TRANSITIONS

See Related Projects below.

RELATED PROJECTS

Sediment Trapping and Transport in Estuaries, Southeastern US, National Science Foundation CAREER Development Program, Kineke PI. This project began in September 1997 and is investigating sediment transport and trapping mechanisms in three estuaries in the southeastern United States

Collaboration with Dr. Miguel Goñi, an organic geochemist (University of South Carolina), began in March 1997. He is investigating the terrigenous inputs of organic matter to sediments in deeper locations in the Gulf of Mexico. We have coordinated our field efforts and are sharing results allowing for an exciting interdisciplinary component to the ongoing study by analyzing the fate of terrestrial organic matter in marine sediments.

Dr. Brent McKee (Tulane University) has ongoing research in the Gulf of Mexico and the Mississippi and Atchafalaya estuaries (state and federal funding), in part to investigate partitioning and exchange of uranium and thorium isotopes where high concentration suspensions are a critical link between seabed and water column chemical exchange.

Water Column Response

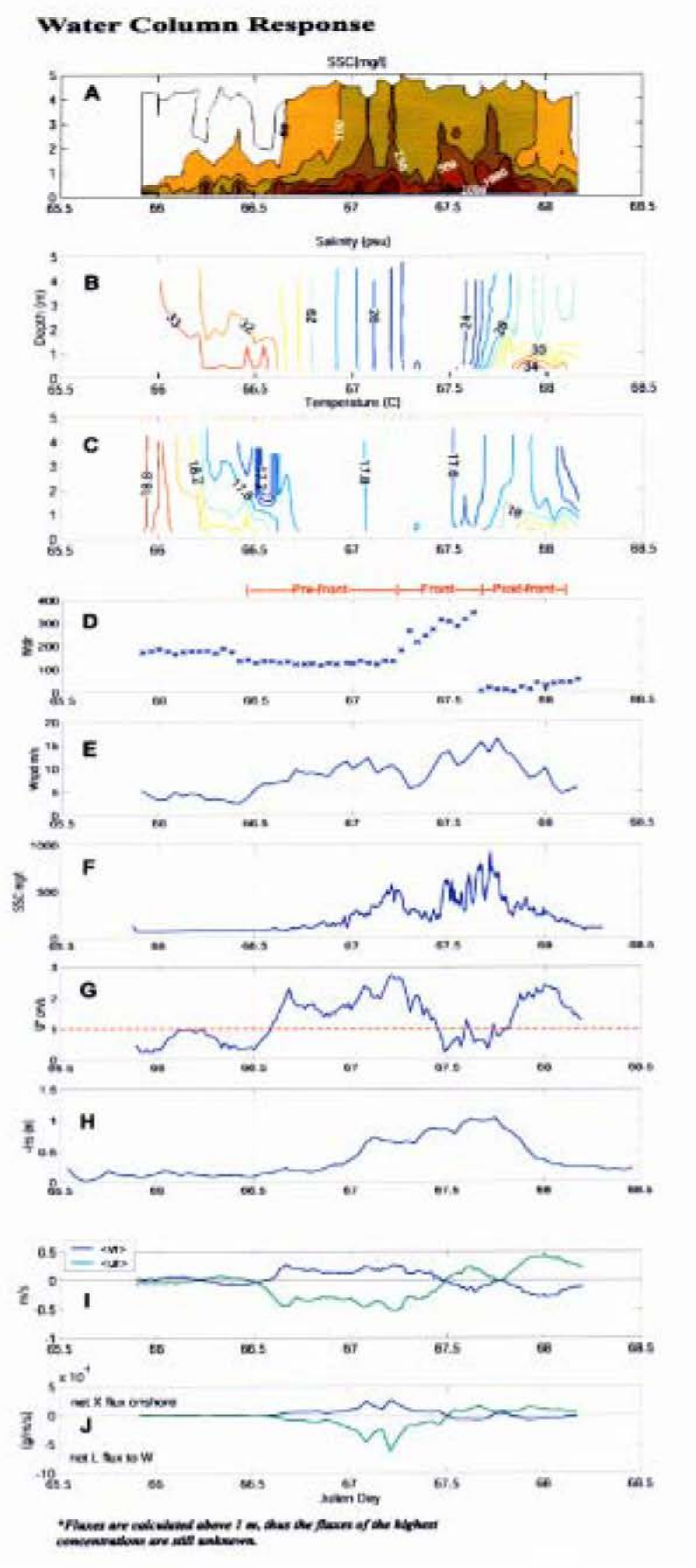

Figure 1. Water Column Response Through a Cold Front Passage.

Time series data of

- ***A) suspended sediment concentration,***
- ***B)salinity,***
- ***C) temperature,***
- ***D, E) wind direction and speed,***
- ***F) nearbottom suspended sediment concentration,***
- ***G) shear velocity (curren only),***
- ***H) significant wave height at 12 m water depth,***
- ***I) depth averaged along- (ur) and across-shore currents (vr) and***
- ***J) along- and across-shore fluxes.***

[The data show rapid breakdown of stratification with increasing wind speed before the cold front passage, enhanced resuspension with an increase in significant wave height, rapid re-establishmen of stratification postfront, and net sediment fluxes onshore and to the west.]

REFERENCES

Dean and Dalrymple, 1991. Water wave Mechanics for Engineers and Scientists. World Scientfic Publishing, New Jersey, 369 pp.

Sternberg, R. W., G. C. Kineke and R. Johnson, 1991. An instrument system for profiling suspended sediment, fluid and flow conditions in shallow marine environments. *Continental Shelf Research* , **11**:109-122.

Trowbridge, J. H. and G. C. Kineke, 1994. Structure and Dynamics of Fluid Muds on the Amazon Continental Shelf. *Journal of Geophysical Research* , **99**:865-874.

PUBLICATIONS

Allison, M.A., G.C. Kineke, E.S. Gordon and M.A. Goni, 2001. Development and reworking of an annual flood deposit on the inner continental shelf off the Atchafalaya River. *Continental Shelf Research*. 20:2267-2294

Gordon, E.S., M.A. Goni, Q.R. Roberts, G.C. Kineke, and M.A. Allison, submitted 2000. Organic matter distribution and accumulation on the inner Louisiana Shelf west of the Atchafalaya River. *Continental Shelf Research*.

Kineke, G.C., K.J. Woolfe, S.A. Kuehl, J. Milliman, T.M. Dellapenna, and R.G.Purdon, 2001. Sediment export from the Sepik River. *Continental Shelf Research*. 20:2239-2266